



Two Color IRFPAs for Navy Missile Warning

Night Operations Symposium

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Outline



- **Missile Warning / TADIRCM concept**
- **Two color midwave IR phenomenology**
- **System live fire test results**
- **Two color focal plane array mantech program**
- **Program plans – transition plan**
- **Summary**



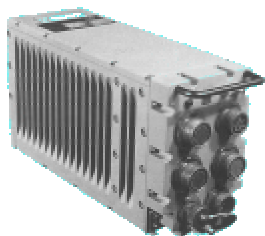
TACAIR DIRCM Concept



To Implement TACAIR DIRCM, Need To:

- *Detect Missile And Angle-of-arrival*
- Track It
- Jam It (Open Loop) With High J/S

Jamming Radiation



Hardware Components:

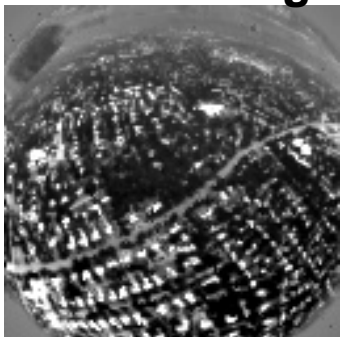
- *Six Two-color IR Staring Sensors(4p Coverage)*
- Signal Processor
- Modulated IR Laser
- Compact Pointer/Trackers (Upper & Lower hemispheres)



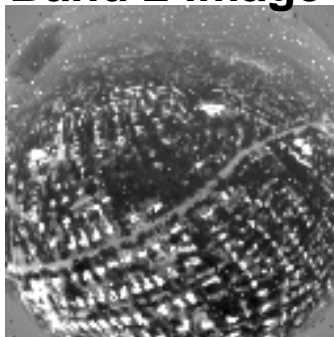
Two Color Infrared Missile Warning Overview

- Point source detection in heavily cluttered scene leads to serious false alarm issue
 - Two color spectral filtering solves false alarm problem

Band 1 image



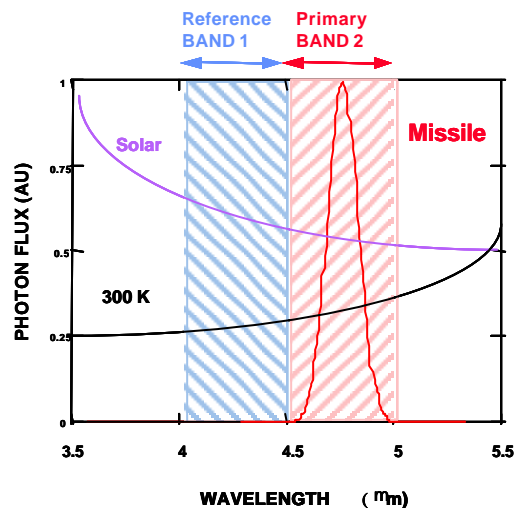
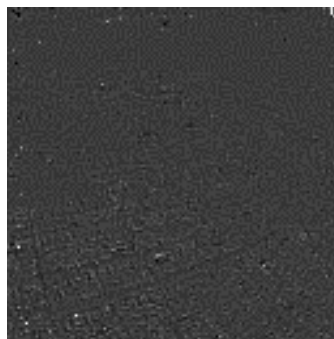
Band 2 image



Spatial filter

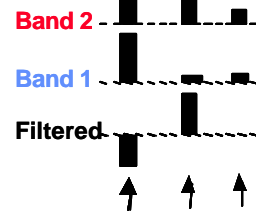


Spectral filter



- Signals in two bands very different for 300 K blackbody, solar, and plume emission

$$F = B2 - a \cdot B1$$



$$W_{i,j} = P_{i,j} - a_{i,j} R_{i,j}$$

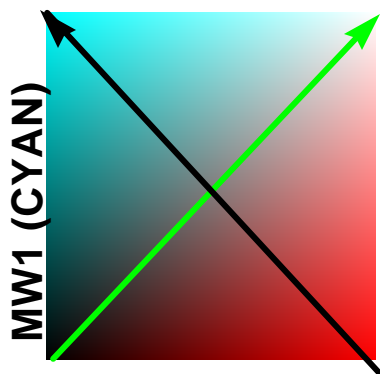
$$a_{i,j} = \frac{\langle P_{i,j} R_{i,j} \rangle}{\langle R_{i,j}^2 \rangle}$$

<> Denotes 5x5 Local Expectation

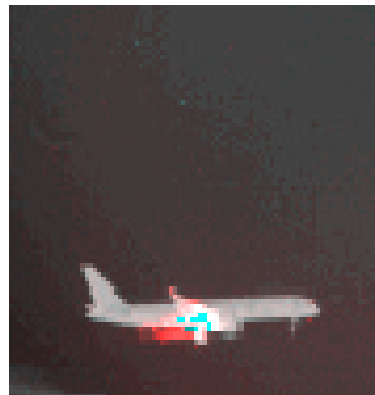
- Temporal processing leads to threat declaration



Two Color MWIR CO2 Emission Detection Real-Time Imaging

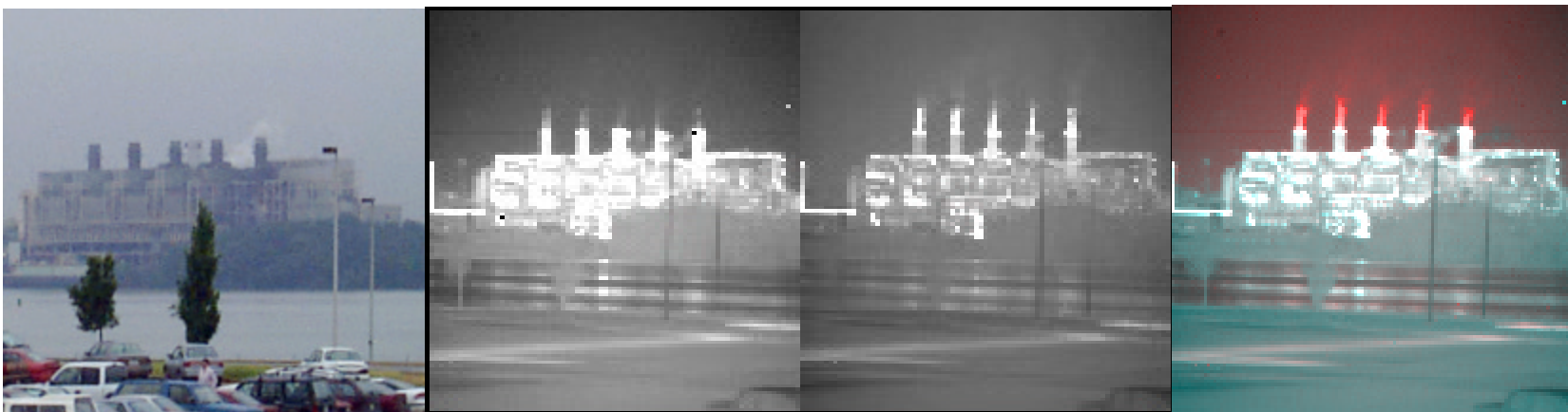


MW2 (RED)



- Commercial aircraft at dusk
- Approximate range 0.5 mi

Coal fired power plant



Visible

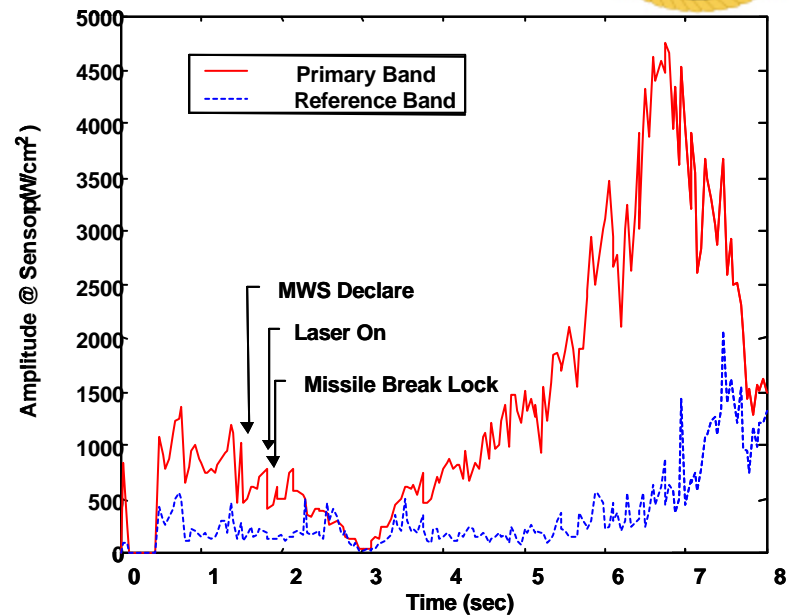
MW1

MW2

Fused 2 color MW

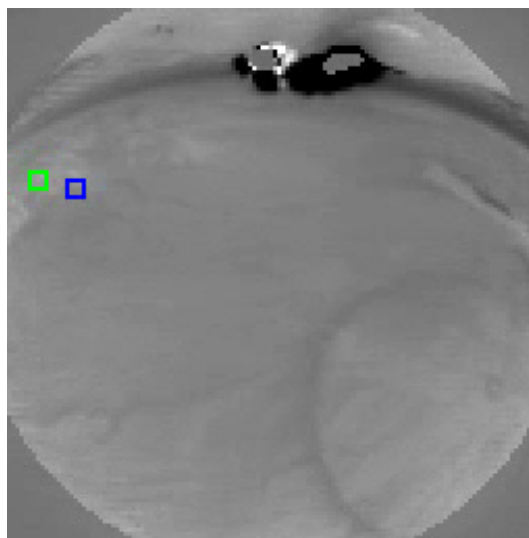


China Lake QF4 SAM Live Fire Results



Event	Time (sec)
Ejector	0.00
Main Motor	0.43
Declare	1.51
Laser on Target	1.80
Missile OBL	1.87
Flare Dispense	5.30

Miss Distance: 653 m





Detection at Launch Allows Geo-Location Of Threats

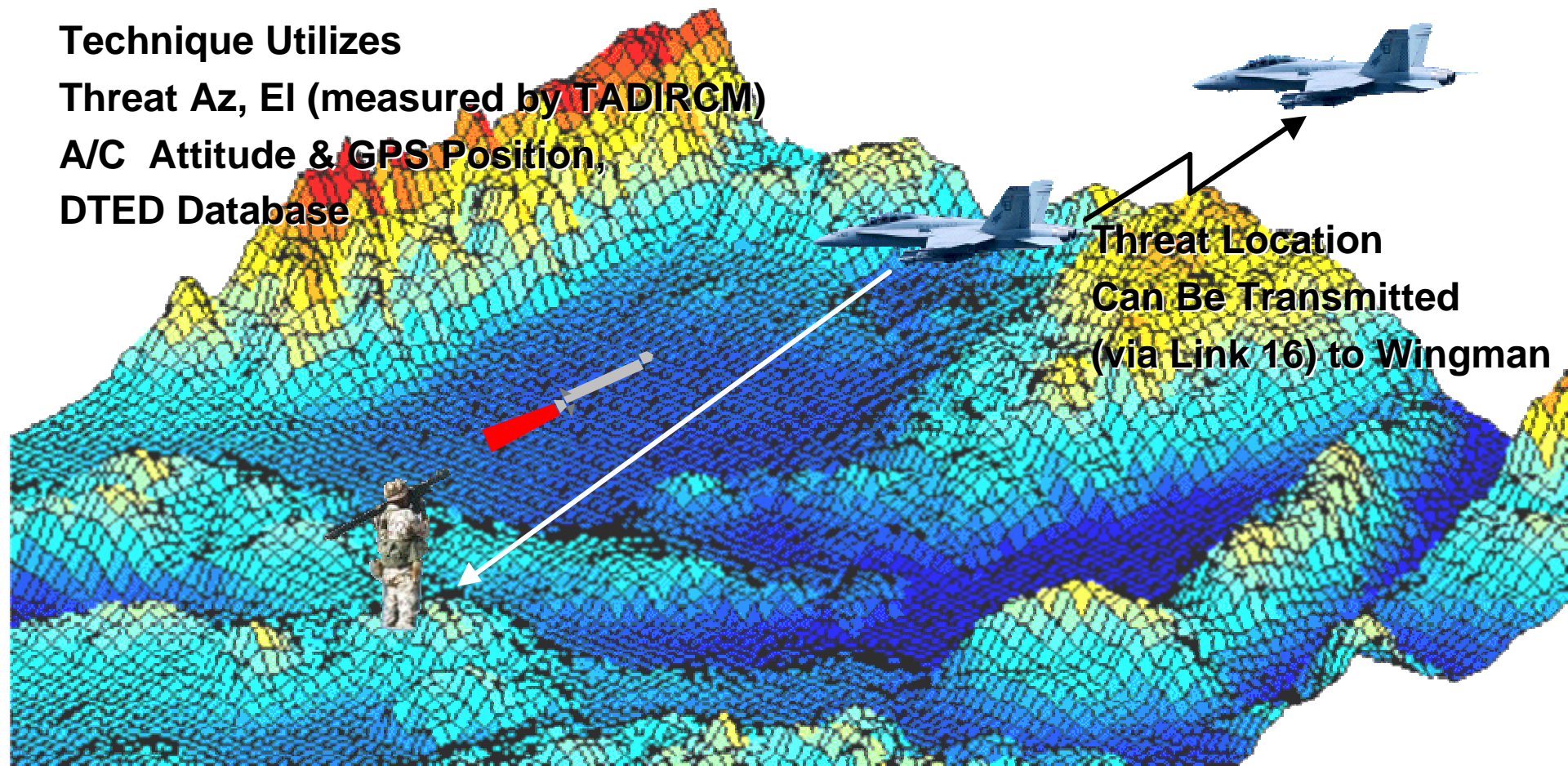


Technique Utilizes

Threat Az, El (measured by TADIRCM)

A/C Attitude & GPS Position,

DTED Database





Navy Advanced IRFPA Mantech Program Objective and Technical Scope



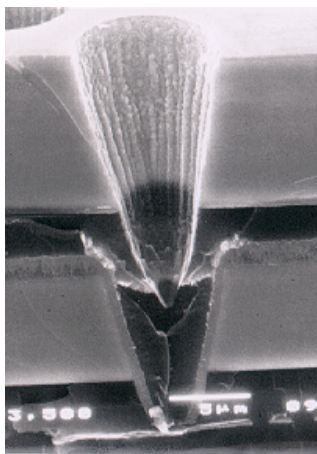
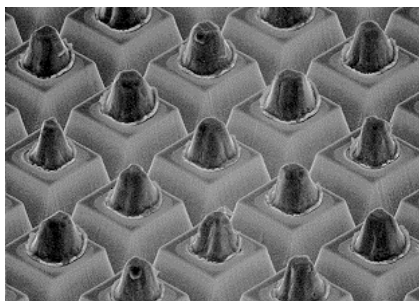
- **Objective**
 - Develop manufacturing techniques to reduce the cost and enhance the availability of two color HgCdTe based mid-wave staring infrared focal plane arrays for missile warning
- **Technical Scope**
 - Detector material growth and characterization
 - Detector device processing techniques
 - Detector-readout circuit interconnect processes
 - Focal plane array test procedures
 - Integrated manufacturing database linked cost and yield models



Manufacturing Technology: Two Color IRFPAs for Navy Missile Warning



**Raytheon(below)
and DRS (right) two
color detectors**



Benefit

- Available low cost arrays for high detection range low false alarm rate IR missile warning sensor for FA/18 EMD program

Objective

- Enhance availability and reduce cost of two color IRFPAs for missile warning sensors

Business Strategy

- \$11 M over three years to two contractors
 - DRS and Raytheon Infrared Operations (with HRL)

Related Efforts

- Army dual band FPAs for FCS
- BMDO/Navy two color LW FPAs for interceptors

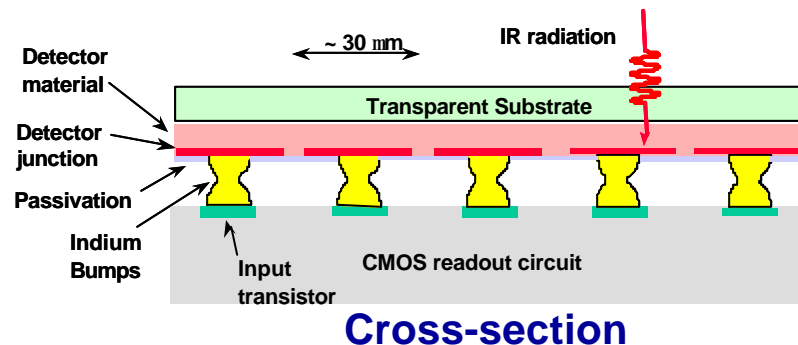
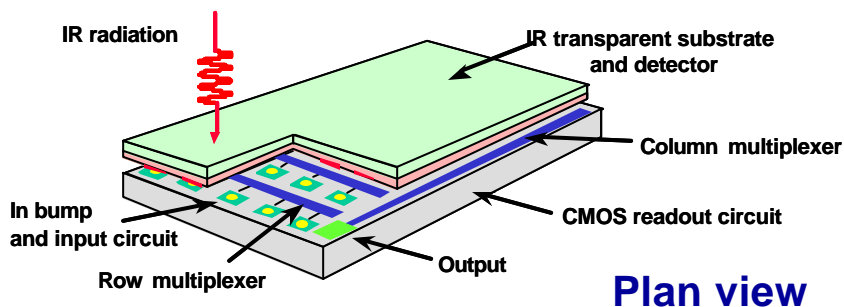
Implementation

- ONR FNC missile warning sensor program FY02-05
- FA/18 missile warning EMD program POM04
- AAR 47 upgrade

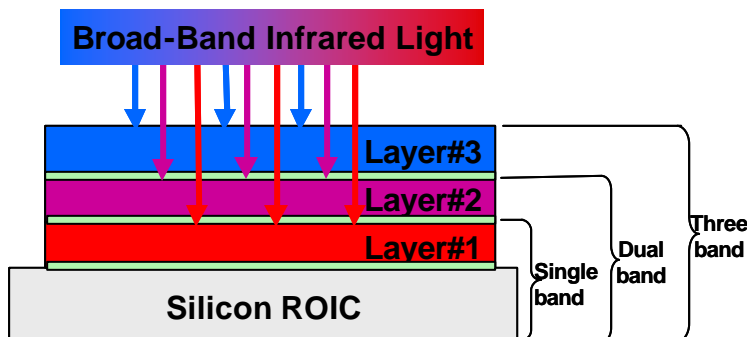


Two Color Focal Plane Technology Basics

Hybrid Focal Plane Array Architecture

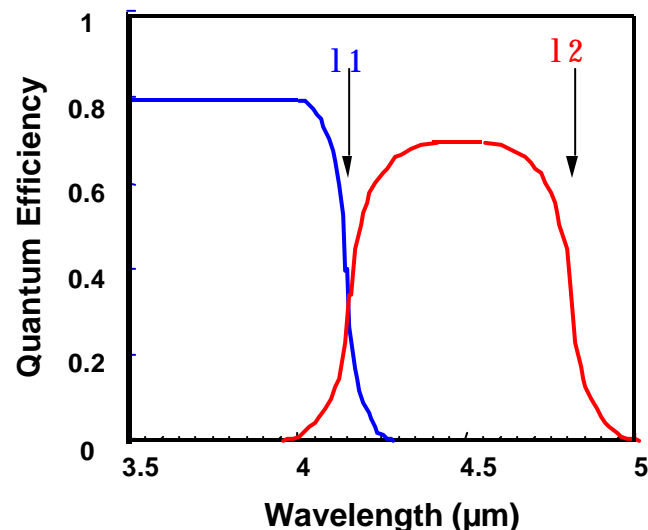


Multi-Color Focal Plane Array Concept



Each layer absorbs radiation up to it's cutoff (bandgap), is transparent to the wavelengths above it's bandgap, which are then collected in subsequent layers

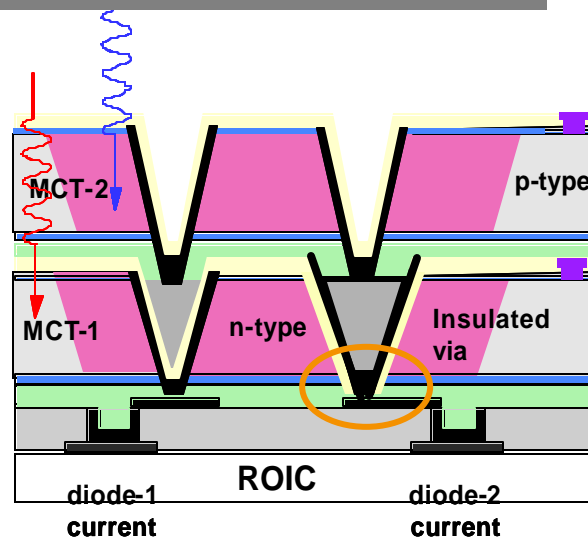
Two Color Spectral Response



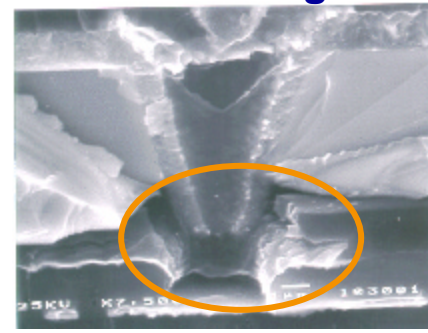
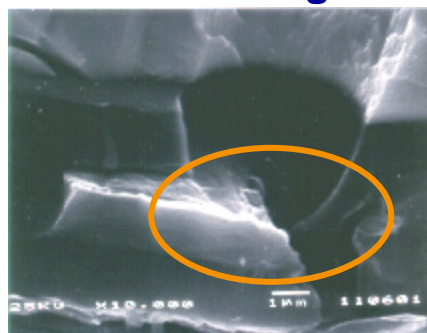


DRS: Approach/Progress

- **High Density Vertically Integrated Photodiode architecture**
 - LPE HgCdTe
 - Ion implanted junctions
 - Lateral photo-generated carrier collection
 - Simultaneous detection
- **Program will build and test ~ 200 focal planes**
- **Baseline yield determined from initial lots: ~5%**
 - Yield limited by bottom via metal – ROIC landing pad alignment
 - Impacts “interconnect operability”



Good via-tab alignment Poor via-tab alignment



Manufacturing process fix

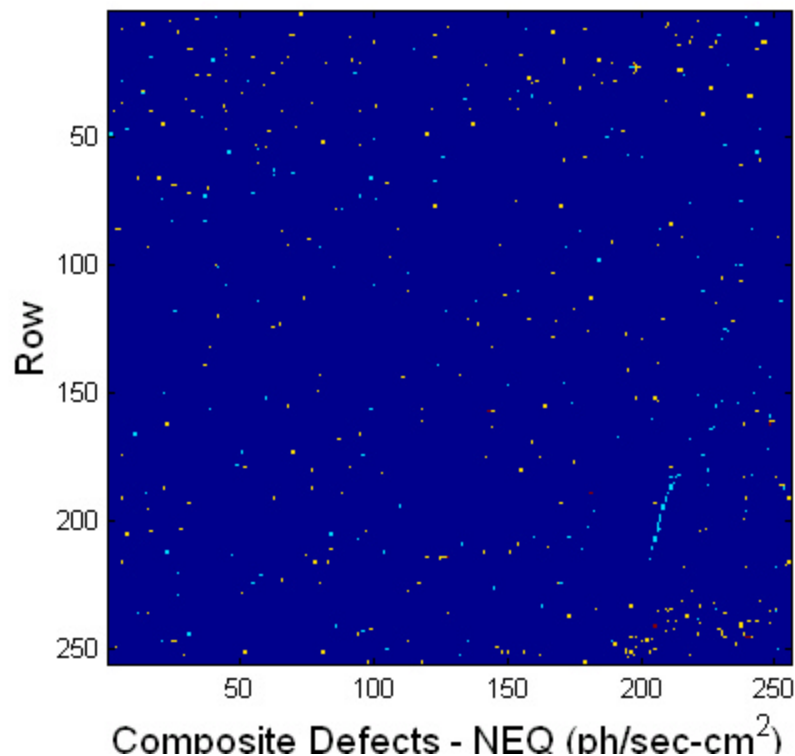
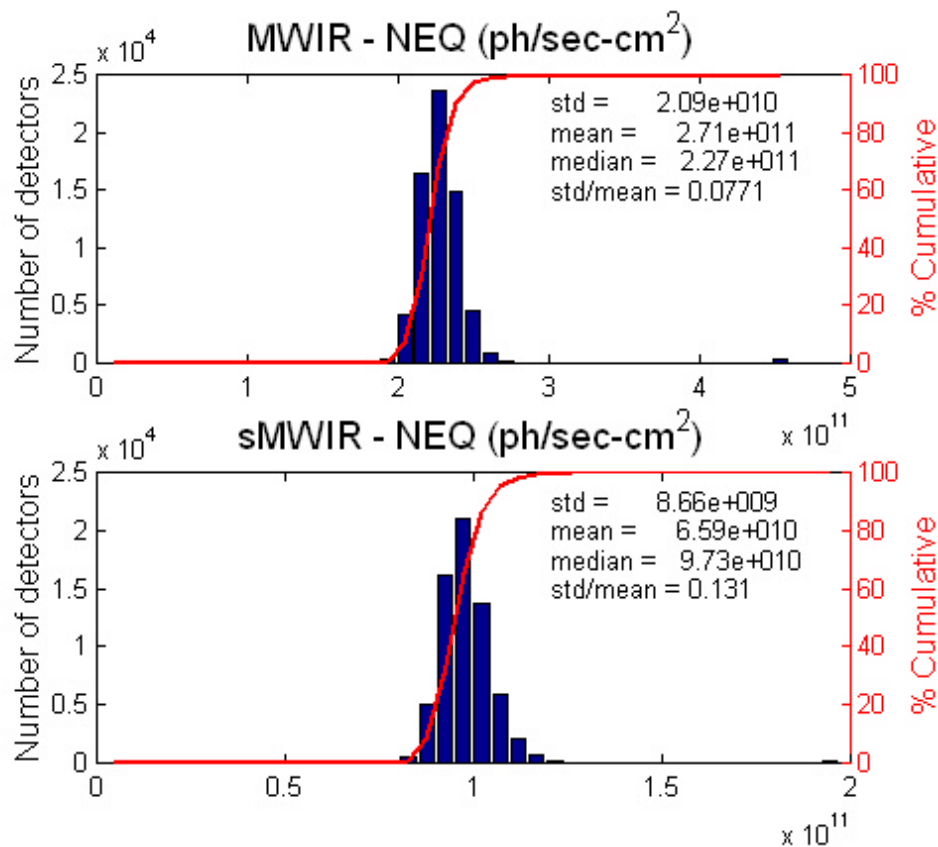
- Detector mask redesign
- Implemented, first lot in 1st quarter CY02



Progress - DRS

Technical Achievement:

- First process development lot at DRS identified optimum via etch process for high NEQ operability (99.3%) arrays

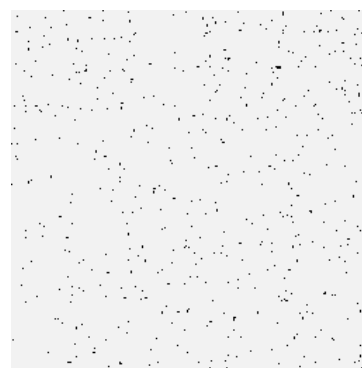
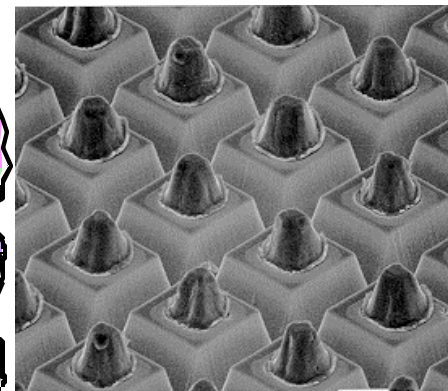
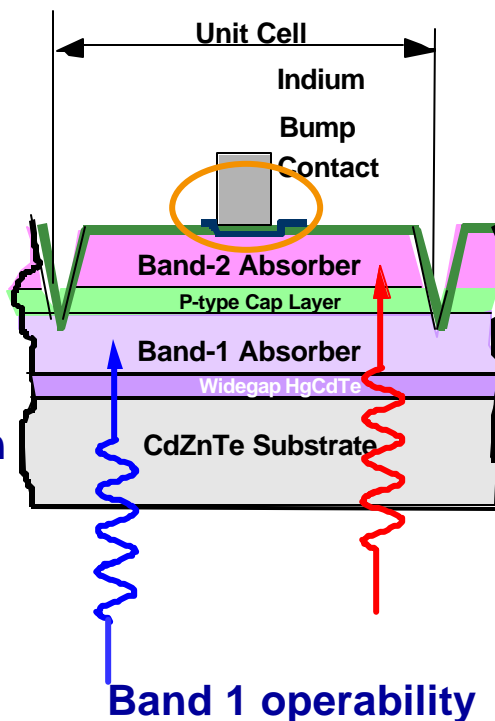


■ No Defect ■ MWIR Defect ■ sMWIR Defect ■ Both

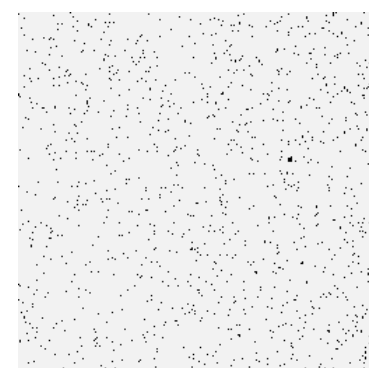


Raytheon: Approach/Progress

- **Triple Layer Heterojunction HgCdTe**
 - Molecular Beam Epitaxial material growth
 - Vertical carrier collection
 - Near 100 % fill factor, perfect registration collocation
 - Single In bump per pixel hybrid
 - Bias switched sequential operation
 - Multiple fast samples of both bands per frame
- Program will build and test ~ 120 focal planes
- Operability initially limited by contact resistance issues
- DOE approach identified surface preparation process enhancement
 - Low resistance ohmic contacts
 - Higher operability focal planes demonstrated



99.1%



98.1%



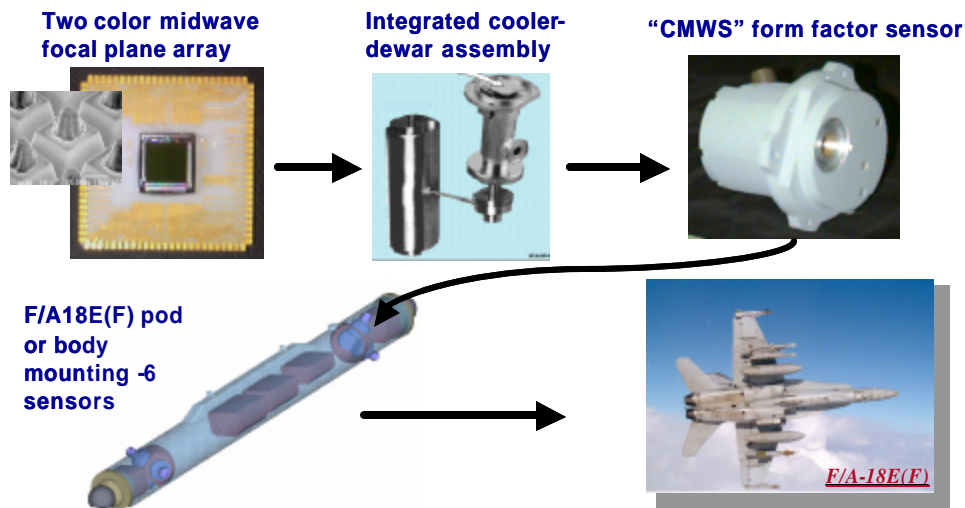
Program Cost- Yield Goals



- **Cost per IRFPA**
 - Program goal is \$30K per FPA vs. present cost of \$200K
 - Need ~\$10K in production quantities (un-funded requirement for additional transfer to high volume production facility or MBE on Si detector material)
- **End to end yield**
 - Program goal is to increase end-to-end yield by a factor of 6
- **Detector die manufacturing cost**
 - Reduce substrate usage by a factor of 2
- **Detector die process complexity**
 - 22 to 17 steps
- **Touch labor hours**
 - E.G. Optimization of double-sided interdiffusion (DSID) process
 - Reduce labor content from 6.5 to 4.4 man-hours/cm²
- **Test costs**
 - Reduce test complexity
 - Go to automated vs man-in-loop test



System Capability Enhancements: Quadrennial Defense Review Operational Goals



- High detection range, low false alarm rate two color IR missile warning for stressing platform dynamics and extreme thermal environments associated with tactical fighter aircraft
- Long range early warning time for helicopters with DIRCM

Deny Enemy Sanctuary

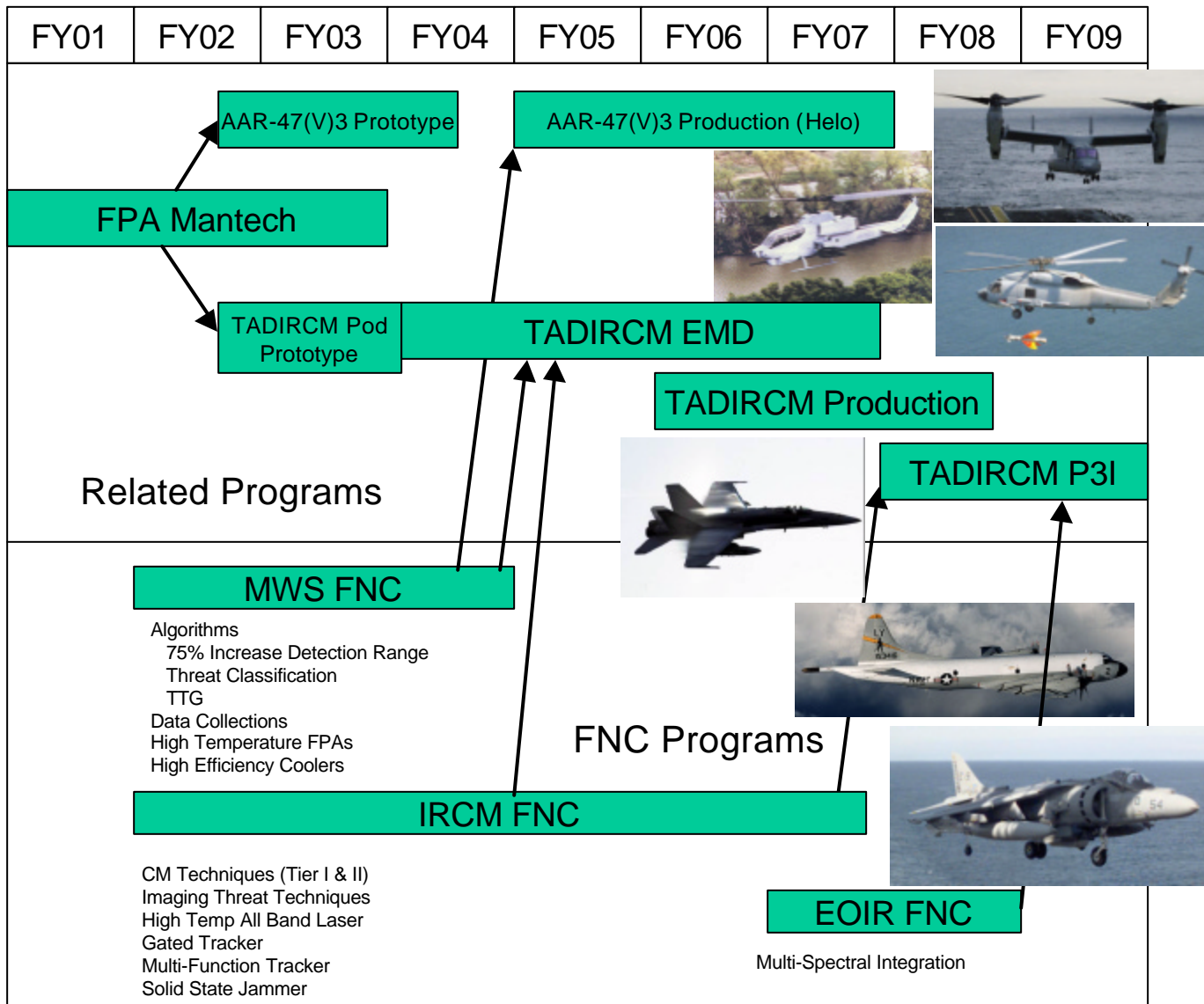
- Long-Range Precision Strike (defeat critical fixed and mobile targets at long range, rapidly, in all terrain and weather conditions in denied areas.)

Project and Sustain US Forces

- Anti-Access Capabilities (... long-range attack lethality, deep strike, ability to mass fires, **strategic transport (sea and air) protection**, battlespace understanding, assured mobility, covertly insert and recover personnel)



Navy Aircraft Self Protection Programs (MWS & DIRCM)





Summary and Conclusions



- **MWS /DIRCM system capability demonstrated in live fire test**
- **Baseline two color IRFPA capability established at both contractors**
 - **Key yield limiters identified**
 - **Manufacturing process enhancements underway to address these**
- **Program is on track to supply focal planes for Navy FNC sensor development efforts**
- **Mantech program cost goals critical for successful completion of FA18E/F TADIRCM program**
- **Prototype AAR47 upgrade for helicopter platforms underway**